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(54) **ARMORED POWER CABLE INSTALLED IN COILED TUBING WHILE FORMING**

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E21B 17/20 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 43/128*** (2013.01); ***E21B 17/206*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 19/084; E21B 43/128; E21B 17/206
See application file for complete search history.

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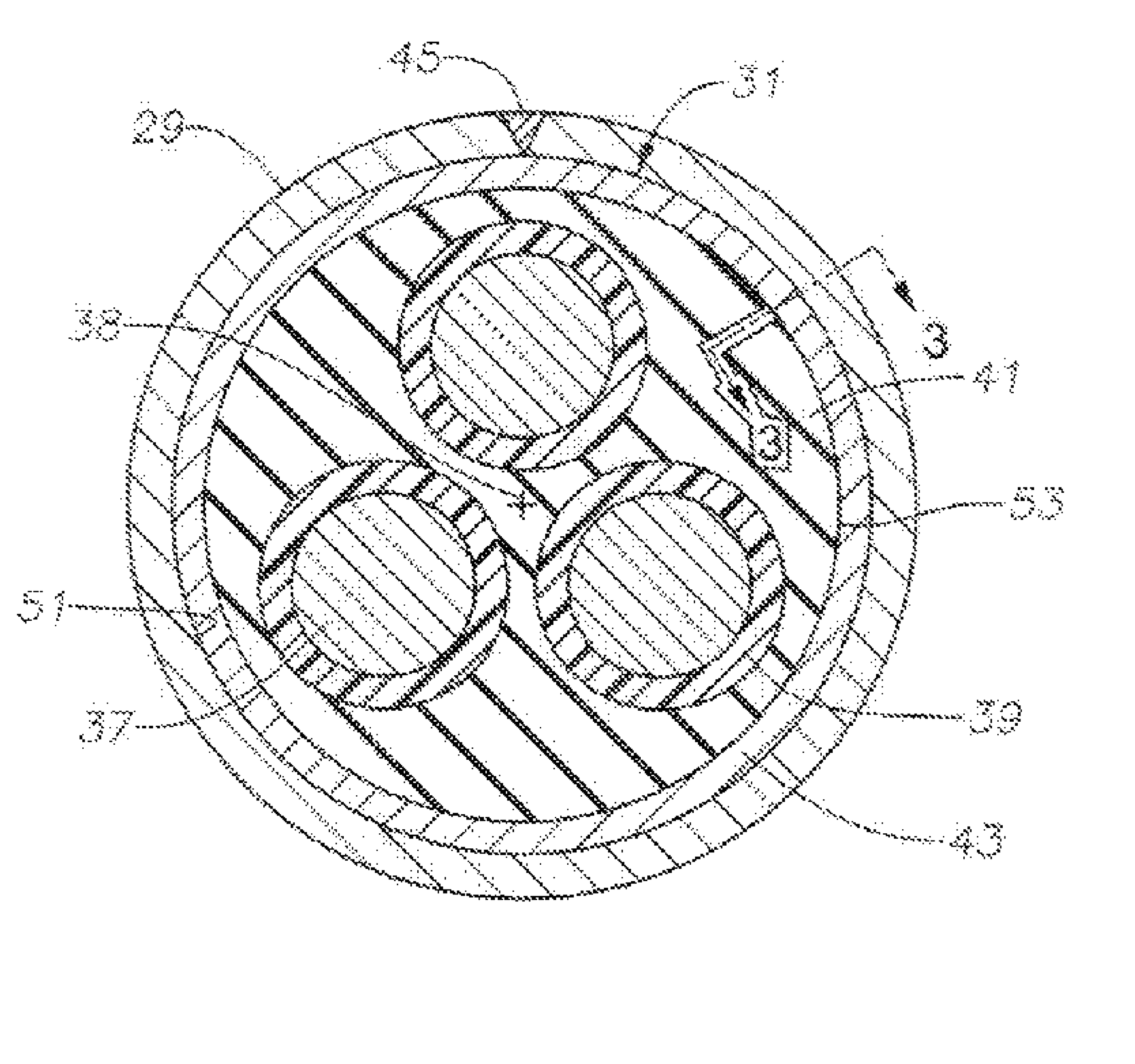
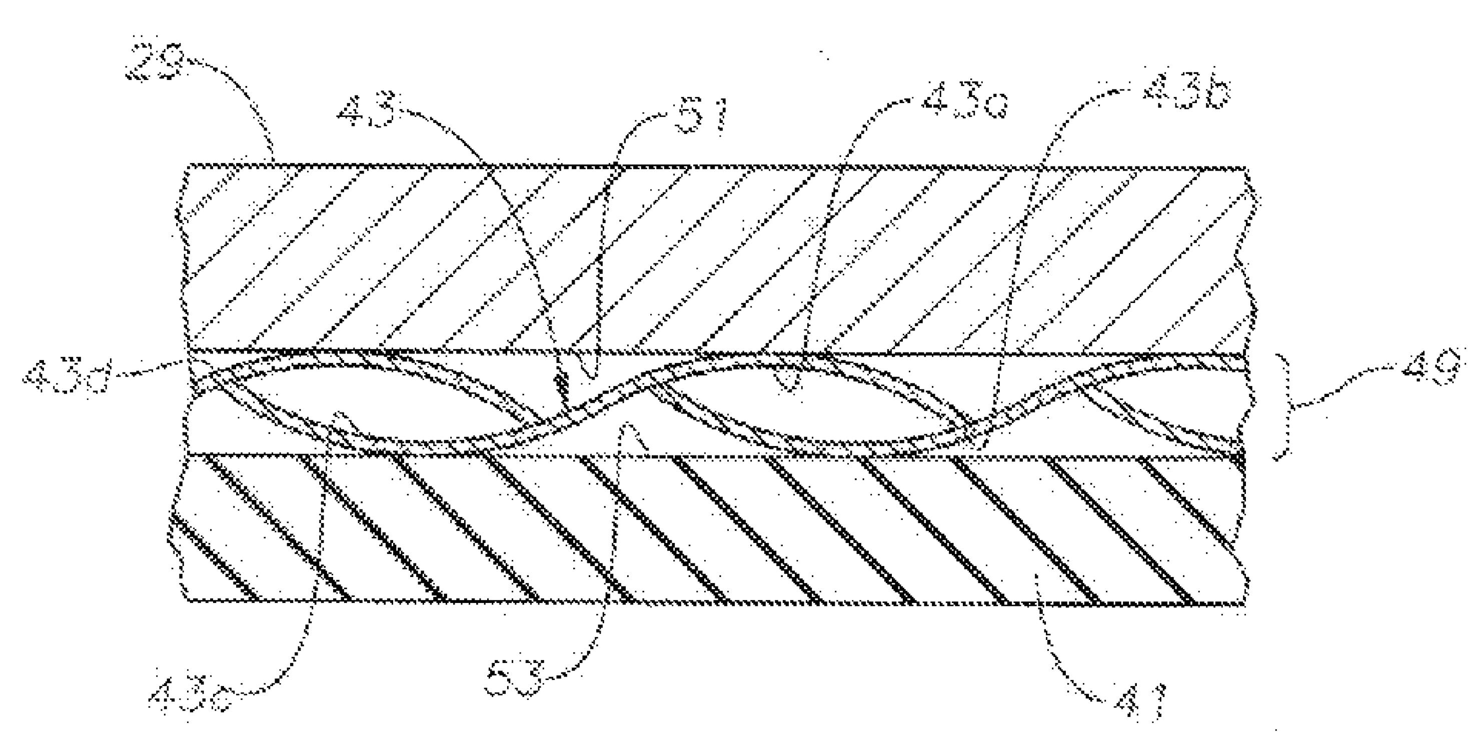
(57) **ABSTRACT**

An electrical submersible well pump assembly includes a pump driven by an electrical motor. A string of tubing connects to the well pump assembly and extends to an upper end of a well. A power cable installed in the tubing has three insulated electrical conductors embedded within an elastomeric jacket. A metal strip has turns wrapped helically around the jacket. The metal strip is compressed between the jacket and the tubing to cause the power cable to frictionally grip the tubing.

15 Claims, 4 Drawing Sheets





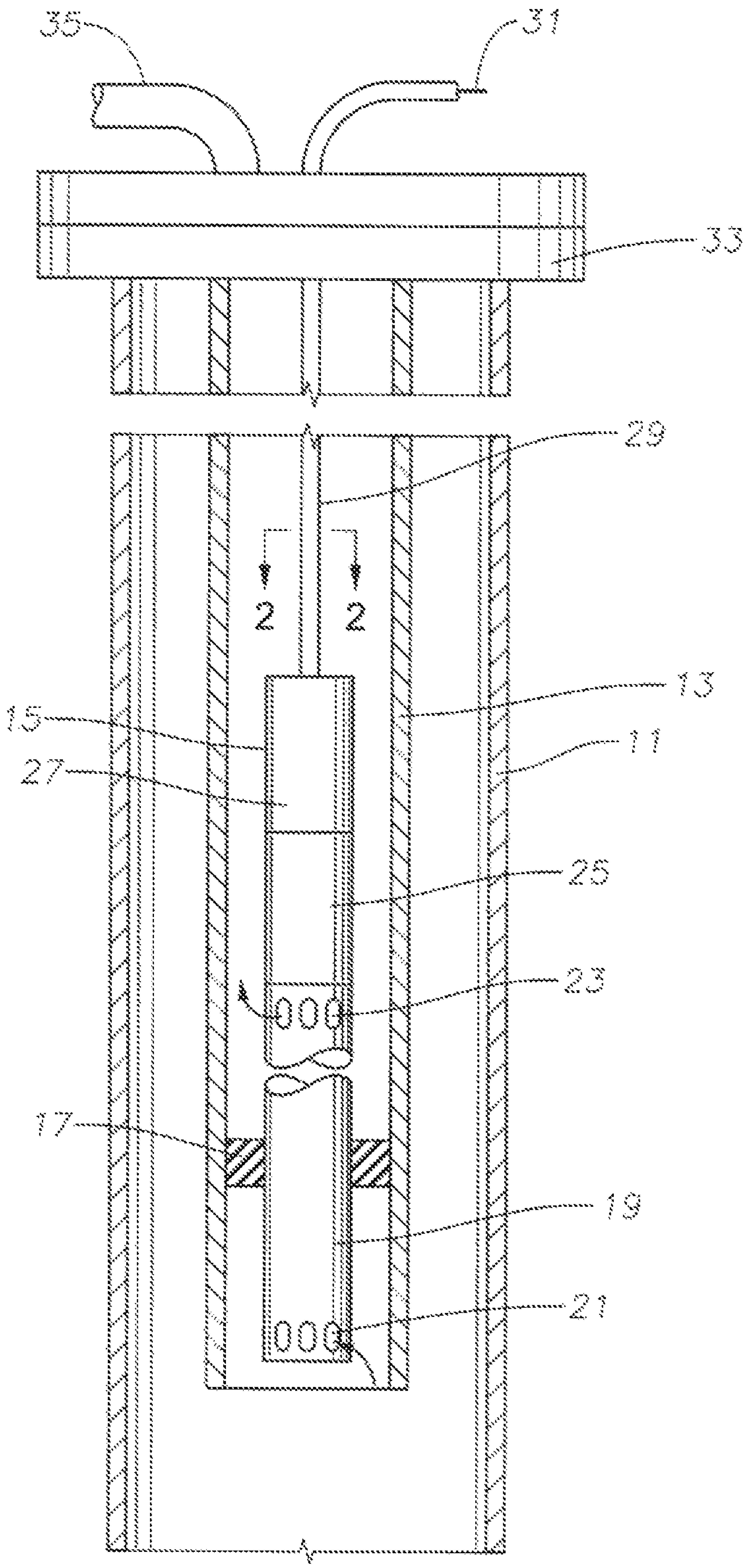


FIG. 1

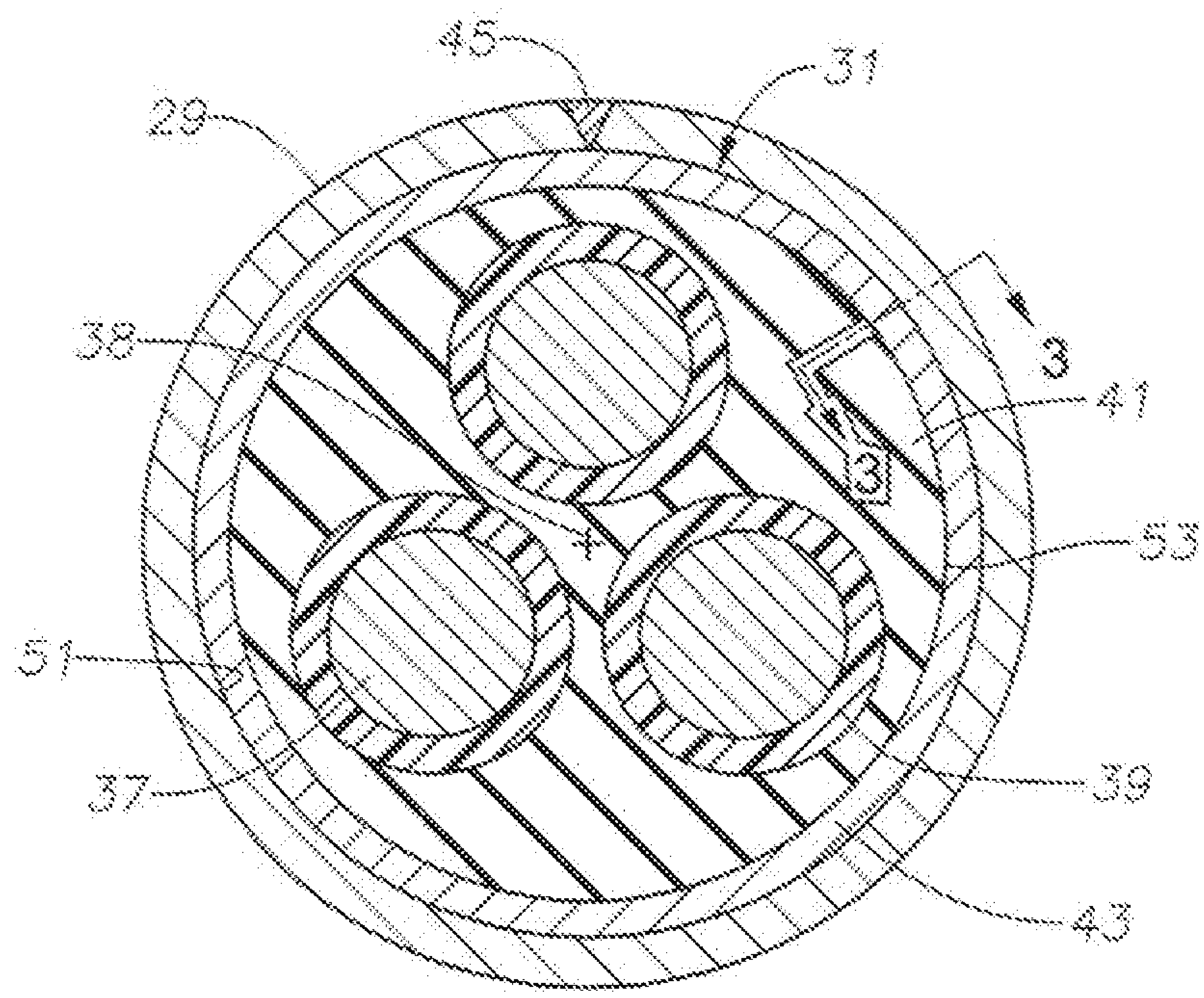


FIG. 2

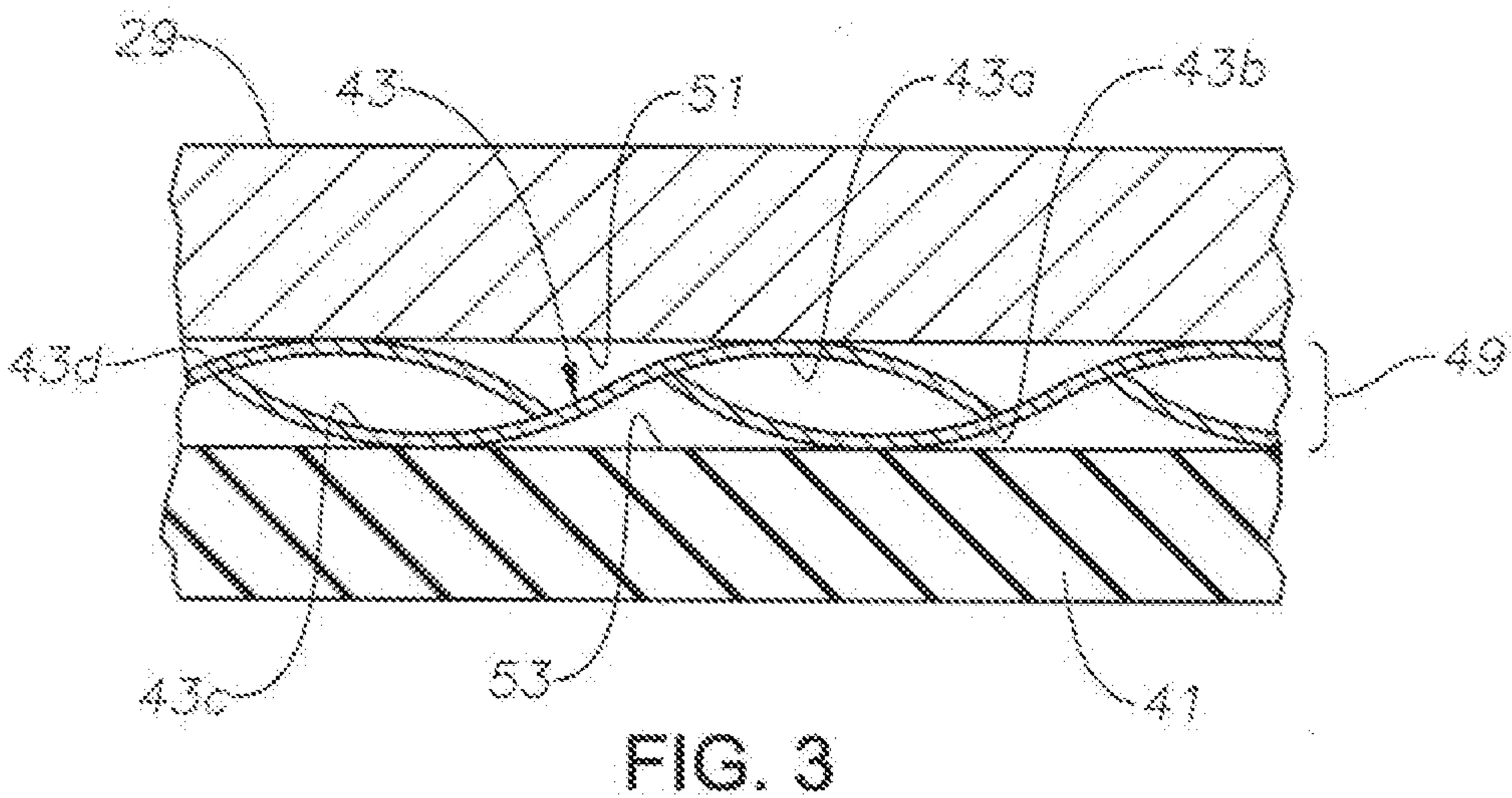


FIG. 3

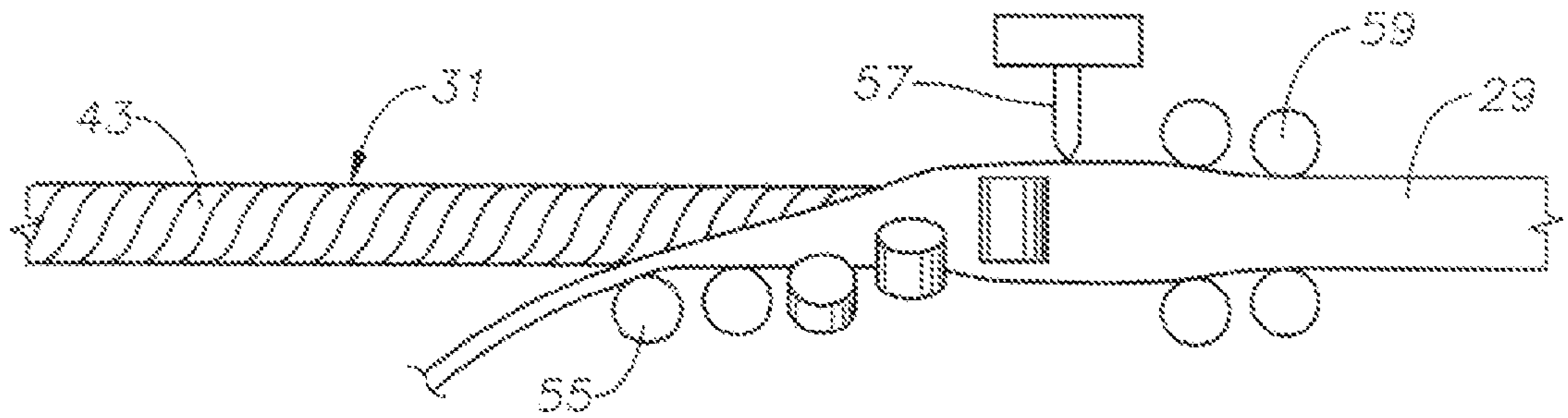


FIG. 4

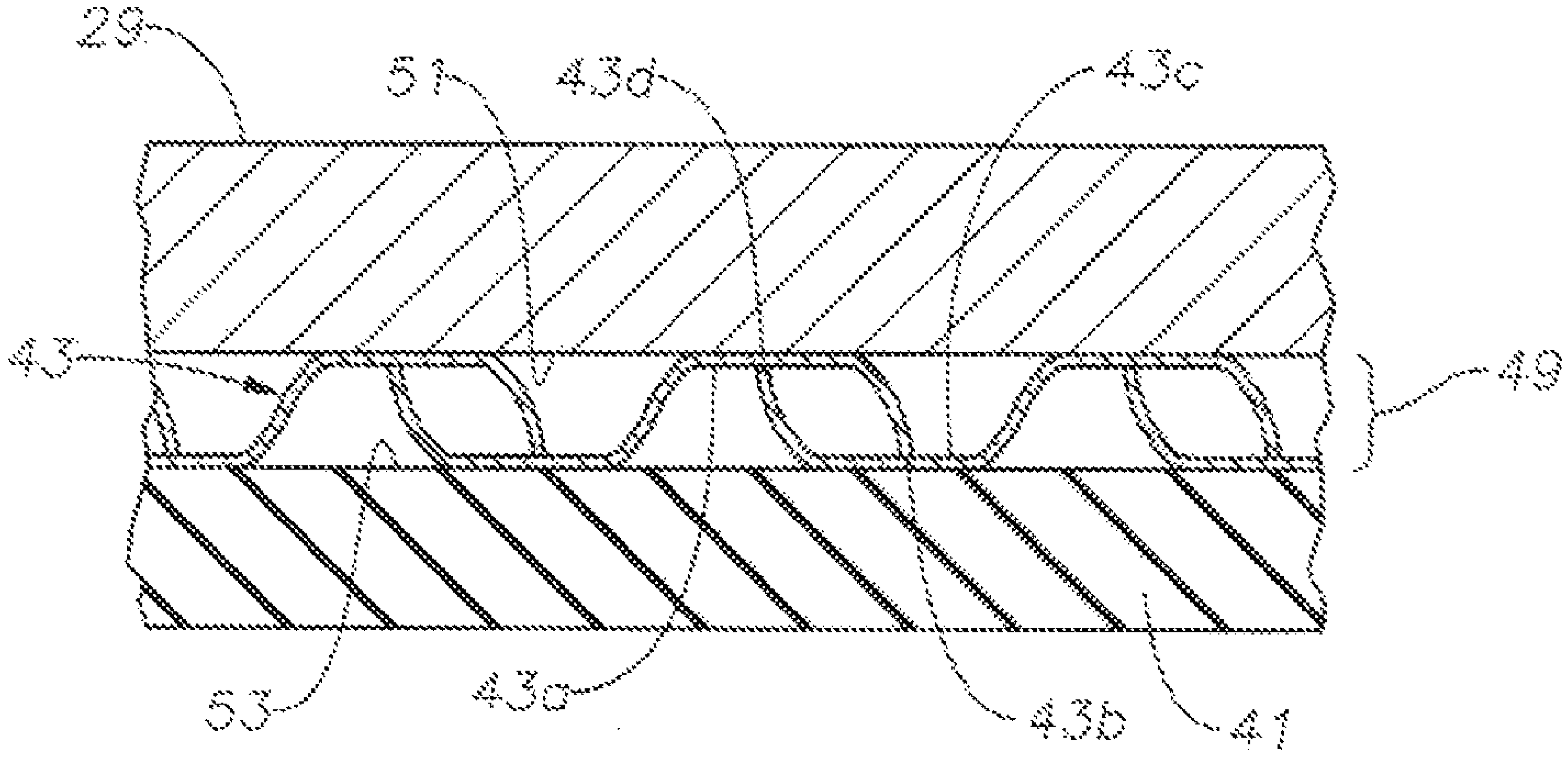


FIG. 5

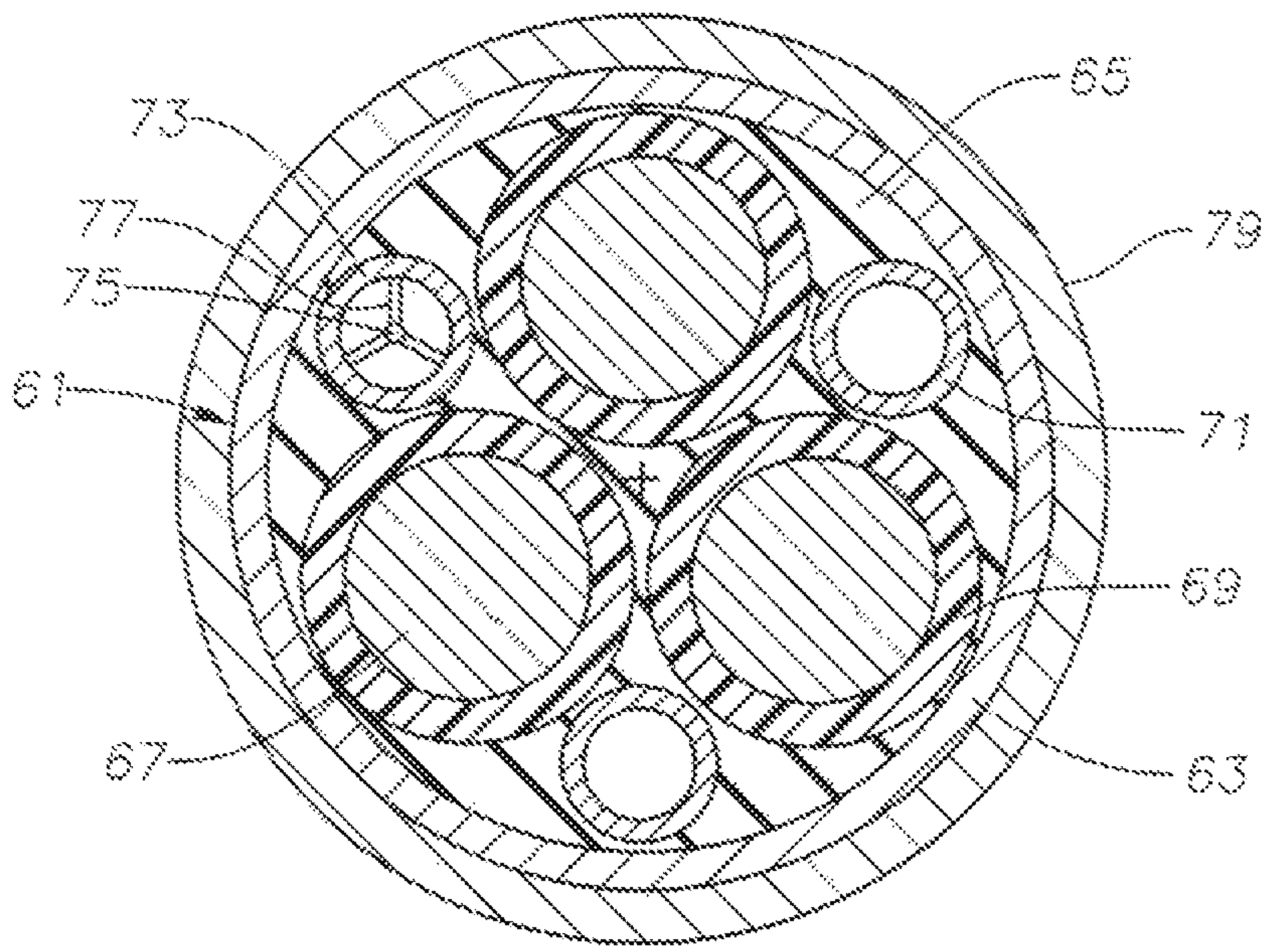


FIG. 6

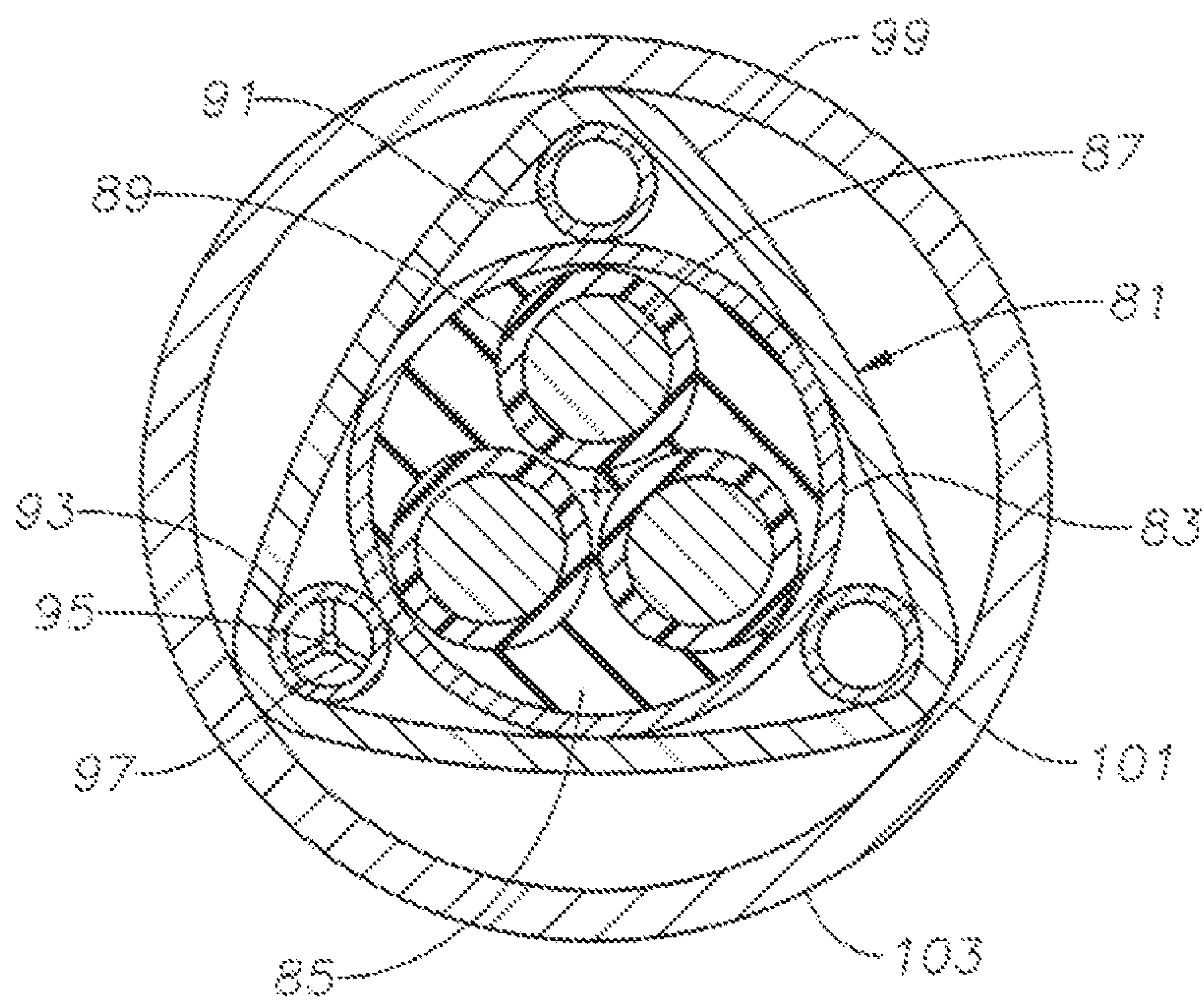


FIG. 7

ARMORED POWER CABLE INSTALLED IN COILED TUBING WHILE FORMING

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority to provisional application 62/037,972, filed Aug. 15, 2014.

FIELD OF THE DISCLOSURE

This disclosure relates in general to electrical submersible pumps for wells and in particular to an armored power cable installed within coiled tubing while the coiled tubing is being formed.

BACKGROUND

Electrical submersible pumps (ESP) are often used to pump fluids from hydrocarbon wells. An ESP includes a motor, a pump, and a seal section that reduces a pressure differential between well fluid on the exterior and dielectric lubricant in the motor interior. An ESP may have other components, such as a gas separator or additional pumps, seal sections and motors in tandem.

A power cable extends from the surface to the motor for supplying three-phase power. Usually, the power cable has three conductors, each of which is separately insulated. A single elastomeric jacket is extruded over the three insulated conductors. A metal strip or armor wraps around the jacket. In round cable, the exterior of the jacket is cylindrical in cross-section. In some installations, a tube extends alongside the armor of the power cable. The tube may be used to convey liquids, or the tube may have an instrument wire located inside. It is known to wrap the tube and the armor together with another metal strip.

In most cases, a string of production tubing supports the ESP, and bands secure the power cable to and alongside the production tubing. When the ESP has to be retrieved for repair or replacement, a workover rig is required to pull the tubing along with the power cable and ESP.

It is desirable to avoid having to employ a workover rig to retrieve the ESP. However, a conventional power cable cannot support its own weight in many wells, thus needs additional support. One technique involves placing the power cable within coiled tubing, which is a continuous length of metal tubing deployed from a reel. The pump discharges up an annular space surrounding the coiled tubing.

Various methods have been proposed and employed to transfer the weight of the power cable to the coiled tubing. In one method, the power cable with armor is pulled through the coiled tubing after the coiled tubing has been formed. Various standoffs or dimples formed in the coiled tubing engage the armor to anchor the power cable within the coiled tubing. In another method, the power cable without an armor is placed in the coiled tubing as the coiled tubing is being formed and seam welded.

SUMMARY

An electrical submersible well pump assembly includes a pump driven by an electrical motor. A string of tubing connects to the well pump assembly and extends to an upper end of the well. A power cable installed in the tubing has three insulated electrical conductors embedded within an elastomeric jacket. A metal strip has turns wrapped helically

around the jacket. The metal strip is compressed between the jacket and the tubing to cause the power cable to frictionally grip the tubing.

Each of the turns of the metal strip overlap with adjacent ones of the turns. Preferably, when viewed in a transverse cross section, each of the turns of the metal strip has a generally S-shaped configuration, defining an outward facing curved valley and an inward facing curved valley, relative to a centerline of the power cable. The inward facing curved valley of each of the turns of the metal strip overlaps the outward facing curved valley of an adjacent one of the turns.

Each of the outward facing and inward facing curved valleys has an edge at a margin of the metal strip. The edge of the inward facing curved valley may be in contact with an outer surface of the outward facing curved valley. The edge of the outward facing curved valley may be in contact with an inner surface of the inward facing curved valley.

Preferably, the metal strip is elastically deformed between the jacket and the tubing. Prior to installation of the power cable in the tubing and after the metal strip is wrapped around the jacket, the metal strip has a radial dimension between an inner side and an outer side that is greater than the radial dimension of the metal strip after installation of the power cable in the tubing.

The power cable may have at least one tube embedded within the jacket alongside the conductors and extending along a length of the power cable. Multiple tubes may be embedded is the jacket and symmetrically spaced relative to a centerline of the power cable. The tube may house an instrument wire or it may be used to convey fluids.

Alternately, the tube may extend alongside and exterior of the jacket. If on the exterior of the jacket, each turn of the metal strip extends around the tube and the jacket. The power cable may have an inner armor strip wrapped helically around the jacket with the tube located exterior of and in contact with the armor strip. The metal strip wraps around the inner armor strip and the tube.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the features, advantages and objects of the disclosure, as well as others which will become apparent, are attained and can be understood in more detail, more particular description of the disclosure briefly summarized above may be had by reference to the embodiment thereof which is illustrated in the appended drawings, which drawings form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the disclosure and is therefore not to be considered limiting of its scope as the disclosure may admit to other equally effective embodiments.

FIG. **1** is a schematic view of an electrical submersible pump assembly supported by coiled tubing containing a power cable in accordance with this disclosure.

FIG. **2** is a transverse cross sectional view of the power cable within coiled tubing of the pump assembly of FIG. **1**.

FIG. **3** is a longitudinal cross sectional view of a portion of the power cable and coiled tubing of FIG. **2**, taken along the line **3-3** of FIG. **2**.

FIG. **4** is schematic view of the coiled tubing being formed and welded around the power cable of FIG. **2**.

FIG. **5** is a longitudinal cross sectional view of the power cable being formed in FIG. **4**, after welding and before swaging.

FIG. **6** is a transverse sectional view of an alternate embodiment of power cable within coiled tubing.

FIG. 7 is a transverse sectional view of another alternate embodiment of power cable within coiled tubing.

DETAILED DESCRIPTION OF THE DISCLOSURE

The methods and systems of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments are shown. The methods and systems of the present disclosure may be in many different forms and should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey its scope to those skilled in the art. Like numbers refer to like elements throughout.

It is to be further understood that the scope of the present disclosure is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation.

Referring to FIG. **1**, the well includes casing **11**, which will be cemented in place. In the embodiment shown, a tubular liner **13** extends through the casing **11**. Liner **13**, which serves as production tubing, is of a conventional type, having sections secured together by threads. Liner **13** is not cemented in the well. An electrical pump assembly (ESP) **15** is supported inside liner **13**. A packer **17** supports ESP **15** in liner **13** and seals the annulus around ESP **15**. Typically, ESP **15** has a stinger (not shown) on its lower end that slides into a polished bore in packer **17**.

ESP **15** includes a centrifugal pump **19** of conventional design. Alternately, pump **19** could be another type of pump, such as a progressing cavity pump or a linear reciprocating pump. In this example, pump **19** has a lower end located below packer **17**. Pump **19** has intake ports **21** below packer **17** and discharge ports **23** located above packer **17** for discharging well fluid pumped from the well. Packer **17** seals the annulus between ESP **15** and liner **13**, and pump **19** draws well fluid from below packer **17** and discharges it into the annulus above packer **17**.

An electrical motor **27**, normally a three phase type, is coupled to a seal section **25**, which in turn connects to pump **19**. Seal section **25** has components to reduce a pressure differential between lubricant contained in motor **27** and the well fluid. A shaft (not shown) extends from motor through seal section **25** and into pump **19** to rotate pump **19**. The upper end of motor **27** has an adapter (not shown), which may be of various types, and serves as means for securing ESP **15** to a lower end of a length of coiled tubing **29**.

Coiled tubing **29** contains a power cable **31** for motor **27** and also supports the weight of power cable **31** and ESP **15** while ESP **15** is being lowered into the well. Although motor **27** is shown mounted above seal section **25** and pump **19**, the assembly could be inverted with motor **27** at the lower end.

Coiled tubing **29** is metal, flexible tubing of a type that will be coiled on a reel (not shown) located at the surface before ESP **15** is deployed. A production tree **33** at the upper end of casing **11** provides pressure and flow control. A flow line **35** extends from tree **33** for delivering well fluids pumped by ESP **15**. Production tree **33** provides support for the upper end of coiled tubing **29**.

Referring to FIG. **2**, power cable **31** includes three electrical conductors **37** for delivering power to motor **27**. Each conductor **37** is of electrically conductive material, such as copper. At least one electrical insulation layer **39** surrounds each conductor **37**. Insulated conductors **37** are twisted about each other along a power cable center line **38**. At any point, when viewed in a transverse cross-section perpendicular to power cable center line **38**, insulated conductors **37** will appear oriented 120 degrees apart from each other. The twisting of insulated conductors **37** enables power cable **31** to be rolled onto a reel.

An elastomeric jacket **41**, also of a conventional material, is extruded around all three of the insulated conductors **37**. Jacket **41** may be either electrically conductive or electrically non-conductive, and it optionally may have longitudinally extending grooves or ridges (not shown) on its cylindrical exterior. Insulation layer **39** and jacket **41** may be of a variety of conventional polymeric insulation materials. Suitable materials include the following: EPDM (ethylene propylene dienne monomer), NBR (nitrite rubber), HNB Hydrogenated Nitrile rubber, FEPM aflas rubber, FKM rubber, polypropylene (PP), polyethylene (PE) cross-linked PE or PP, thermoplastic elastomers, fluoropolymers, thermoplastics or thermoset elastomers.

Power cable **31** includes a metal band, tape or strip **43** wrapped helically around jacket **41**. Metal strip **43** is preferably formed of a steel material, although Monel, aluminum copper or other metals are feasible. The turns of metal strip **43** overlap and preferably interlock with each other. As shown also in FIG. **3**, metal strip **43**, also referred to as an armor, may have a generally S-shaped or sinusoidal shaped configuration in cross section. Metal strip **43** has an inward facing curved valley or concave surface **43*a*** that terminates in an inward facing edge **43*b***, relative to power cable center line **38** (FIG. **2**). Metal strip **43** has an outward facing curved valley or convex surface **43*c*** that terminates in an outward facing edge **43*d***. Inward and outward facing valleys **43*a***, **43*c*** join each other in a curved central transition area. The edges **43*b*** and **43*d*** of one turn of metal strip **43** overlap with edges **43*b***, **43*d*** of adjacent turns of metal strip **43**. Edges **43*b*** and **43*d*** are at opposite margins of metal strip **43**. Inward facing edge **43*b*** extends into and may touch the outer surface of outward facing valley **43*c*** of an adjacent turn. Outward facing edge **43*d*** extends into and may touch the inner surface of inward facing valley **43*a*** of the other adjacent turn. Metal strip **43** thus fully surrounds jacket **41**.

Metal strip **43** is radially deformed from an original transverse or radial dimension prior to installation of power cable **31** in coiled tubing **29** to a smaller radial dimension. An annular gap **49** exists between inner diameter **51** of coiled tubing **29** and the outer diameter **53** of jacket **41**. After power cable **31** is installed within coiled tubing **29**, annular gap **49** has a radial thickness or dimension that is less than the initial radial dimension of metal strip **43** measured from the innermost point of outward facing valley **43*c*** to the outermost point of inward facing valley **43*a***. The smaller dimension of annular gap **49** deforms metal strip **43** to the same radial dimension, thereby placing metal strip **43** in tight frictional engagement with coiled tubing inner diameter **51**. The deformation of metal strip **43** may be elastic or permanent. Apart from coiled tubing **29**, power cable **31** typically will not support its own weight within an oil producing well because of the long length. The friction created by metal strip **43** being deformed against inner diameter **51** of coiled tubing **29** is adequate to transfer the weight of power cable **31** to coiled tubing **29**.

Power cable **31** is formed, then installed in coiled tubing **29** while coiled tubing **29** is being manufactured. Power cable **31** will be formed conventionally, with metal strip **43** wrapped tightly around and in frictional engagement with jacket **41**. When power cable **31** is installed during manufacturing, coiled tubing **29** is rolled from a flat strip into a cylindrical shape, and a weld is made of the abutting edges, as shown by weld seam **45**.

FIG. **4** schematically illustrates a manufacturing process of installing power cable **31** in coiled tubing **29** while the coiled tubing is being manufactured. Forming rollers **55** deform a flat plate into a cylindrical configuration around power cable **31** in a continuous process. Then a welding device, such as a laser torch **57**, welds seam **45**. Metal strip **43** avoids direct contact of laser **57** with the elastomeric jacket **41**, which otherwise would create smoke. The smoke inhibits effective welding of weld seam **45**. Metal strip **43** also reduces the amount of heat received by jacket **41** from laser torch **57**.

After welding, coiled tubing **29** undergoes a swaging process with swage rollers **59** to reduce the initial diameter of coiled tubing **29** to a final diameter. Referring to FIG. **5**, before the swaging process, annular gap **49** will have a greater radial thickness than afterward (FIG. **3**). The radial dimension of metal strip **43** is likewise greater before the swaging process than afterward. Before the swaging process, metal strip **43** may be touching coiled tubing inner diameter **51**, or there could be a slight clearance, or even some radial compression. The swaging process causes the radial dimension of annular gap **49** (FIG. **5**) to reduce to the radial dimension of annular gap **49** to that shown in FIG. **3**. The reduction in radial dimension more tightly compresses metal strip **43** to increase the frictional engagement of metal strip **43** with coiled tubing **29**. During the swaging process, inward facing edges **43***b* slide on outward facing valleys **43***c*. Outward timing edges **43***d* slide on inward facing valleys **43***a*. Valleys **43***a* and **43***c* reduce in radial dimension during the swaging process. The material of jacket **41** is preferably non compressible, although jacket **41** can be deformed. The outer diameter **53** of jacket **41** thus may remain constant during the swaging process.

As an example, metal strip **43** may be formed of a material having a thickness in the range from 0.003 to 0.040 inch. While being radially deformed by the swaging process, the radial dimension of metal strip **43** and gap **49** map decrease by an amount in the range from about 0.005 to 0.025 inch. In this example, the swaging process thus decreases coiled tubing inner diameter **51** by an amount from about 0.010 to 0.050 inch, but it could be more.

Coiled tubing **29** is not annealed after the welding process, thus may be ready for use after the swaging process. During operation of ESP **15** (FIG. **1**), the spaces between inward facing valleys **43***a* and jacket outer diameter **53** and the spaces between outward facing valleys **43***c* and coiled tubing inner diameter **51** provide additional room for the material of jacket **41** to distort and flow to relieve forces resulting from thermal expansion.

FIG. **6** illustrates an alternate embodiment in a transverse cross section. Power cable **61** has a metal strip **63** wrapped helically around the cylindrical exterior of elastomeric jacket **65**. Metal strip **63** may have the same configuration as metal strip **43** of the first embodiment. Three electrical motor power conductors **67** are encased in jacket **65**, each conductor **67** having at least one or more insulation layers **69**. Conductors **67** are spaced 120 degrees apart from each other relative to the centerline of power cable **61**.

In this example, two fluid conveying tubes **71** and one signal wire tube **73** are shown embedded within jacket **65**. Tubes **71** and **73** extend alongside conductors **67** the length of power cable **61**. Normally, conductors **67** twist relative to each other along the length of power cable **61**, and tubes **71**, **73** will also twist in the same manner. Tubes **71**, **73** are preferably symmetrically spaced around the centerline of power cable **61**. If three tubes **71**, **73** are employed, preferably they are located 120 degrees apart from each other relative to the centerline of power cable **61**. Each tube **71**, **73** is positioned between two of the conductors **67**. The centerline or axis of each tube **71**, **73** may be slightly farther from the centerline of power cable **61** than the centerlines of conductors **67**. Tubes **71**, **73** optionally may be smaller in diameter than the outer diameters of insulation layers **69**. Preferably, the elastomeric material of jacket **65** is extruded completely around each tube **71**, **73**. Tubes **71**, **73** may be formed of a metal, such as Monel.

Fluid conveying tubes **71** are hollow and employed to convey fluids to and/or from ESP **15** (FIG. **1**). For example, the fluids may comprise hydraulic fluid and/or liquid chemicals employed to assist in well fluid production.

Signal wire tube **73** contains an instrument wire **75** for transmitting signals to and/or from ESP **15** (FIG. **1**). The signals may concern well fluid parameter measurements, such as pressure and temperature. As an example, instrument wire **75** may be supported in in a standoff **77** in signal wire tube **73**, and the remaining portions of signal wire tube **73** may be filled with an electrical insulation powder. The number of signal wire tubes **73** and fluid conveying tubes **71** may vary. In some embodiments, all of the tubes within the jacket of the power cable may comprise signal tubes, or all may comprise fluid conveying tubes. A single tube within a power cable is feasible.

Power cable **61** is installed within coiled tubing **79** while coiled tubing **79** is being formed and seam welded in the same manner as in the first embodiment. Metal strip **63** will be radially deformed between jacket **65** and the inner diameter of coiled tubing **79** to frictionally grip the inner diameter of coiled tubing **79**. The radial dimension of metal strip **65** decreases from its initial dimension while coiled tubing **79** is swaged after being welded. Preferably, the radial deformation of metal strip **63** is elastic, but it could be permanent. Metal strip **63** creates an outward bias force against the inner surface of coiled tubing **79**.

FIG. **7** illustrates another embodiment. Power cable **81** has an inner metal strip **83**, also referred to as a metal armor strip, wrapped around an elastomeric jacket **85** in the same manner as in the first two embodiments. Inner metal strip **83** may have the same configuration as metal strip **43** of FIG. **2**. Jacket **83** is extruded around three electrical conductors **87**, each having at least one insulation layer **39**.

In this example, two fluid conveying tubes **91** and a signal wire tube **93** form a part of power cable **81**. Rather than being embedded within jacket **85** as in the embodiment of FIG. **6**, tubes **91**, **93** are located on the exterior of inner metal strip **83**. Fluid conveying tubes **91** serve to convey fluid to and/or from ESP **15** (FIG. **1**). Signal wire tube **93** contains an instrument wire **95** to transmit signals to and/or from ESP **15**. Instrument wire **95** may be supported in a standoff **97** surrounded by an electrical insulation powder.

The number of tubes **93**, **95** may vary. All of the tubes **93**,**95** may serve to convey fluid, or all may serve to transmit signals. Preferably tubes **93**, **95** are symmetrically spaced around inner metal strip **13**. In this example, tubes **93**, **95** are spaced 120 degrees apart from each other relative to the centerline of power cable **81**. Tubes **93**, **95** are smaller in outer diameter than the outer diameter of inner metal strip **83** and optionally may have a smaller outer diameter than the outer diameter of insulation layers **69**.

An outer metal strip **99** wraps helically around the assembled tubes **93**,**95** and inner metal strip **83**. Outer metal strip **99** may have the same configuration as metal strip **43** of the first embodiment. With three tubes **93**, **95**, outer metal strip **99** has a generally triangular appearance when viewed in the transverse cross section of FIG. **7**. Outer metal strip **99** has three corner portions **101**, each of which extends around in tight contact with the outer portion of one of the tubes **91**, **93**. Outer metal strip **99** has intermediate portions between corner portions **101** that will contact inner metal strip **83** at a point equidistant between two of the tubes **91**, **93**.

Power cable **81** is installed within coiled tubing **103** in the same manner as the other embodiments. As coiled tubing **103** is being swaged after its seam is welded, inner surface portions of coiled tubing **103** will contact and radially deform corner portions **101** of outer metal strip **99**. Initially, the transverse or radial dimension of outer metal strip **99** at corner portions **101** is greater. The swaging process of coiled tubing **103** reduces the radial dimensions at corner portions **101**, causing corner portions **101** to frictionally grip inner surface portions of coiled tubing **103**. The reduction in radial thickness creates a bias force of corner portions **101** against inner surface portions of coiled tubing **103**. The deformation may be elastic or permanent.

While the disclosure has been shown in only a few of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the disclosure.

The invention claimed is:

1. An electrical submersible well pump assembly, comprising:
- a pump driven by an electrical motor;
- a string of tubing connected to the well pump assembly and adapted to extend to an upper end of a well;
- a power cable installed in the tubing, the power cable comprising:
- three insulated electrical conductors embedded within an elastomeric jacket;
- a metal strip having turns wrapped helically around the jacket;
- the metal strip being compressed between the jacket and the tubing to cause the power cable to frictionally grip the tubing; and wherein:
- when viewed in a transverse cross section, each of the turns of the metal strip defines an outward facing curved valley and an inward facing curved valley, relative to a centerline of the power cable, the outward facing curved valley joining the inward facing curved valley at a curved transition area, each of the outward facing and inward facing curved valleys having an edge at a margin of the metal strip;
- the edge of the inward facing curved valley being in contact with an outer surface of the outward facing curved valley; and
- the edge of the outward facing curved valley being in contact with an inner surface of the inward facing curved valley.

2. The assembly according to claim **1**, wherein the metal strip is elastically deformed between the jacket and the tubing.

3. The assembly according to claim **1**, wherein prior to installation of the power cable in the tubing and after the metal strip is wrapped around the jacket, the metal strip has a radial dimension between an inner side and an outer side that is greater than the radial dimension of the metal strip after installation of the power cable in the tubing.

4. The assembly according to claim **1**, further comprising at least one tube embedded within the jacket alongside the conductors and extending along a length of the power cable.

5. The assembly according to claim **1**, further comprising:
- at least one tube extending alongside and exterior of the jacket along a length of the power cable; and
- wherein each turn of the metal strip extends around the tube and the jacket.

6. The assembly according to claim **1**, further comprising:
- a metal armor strip wrapped helically around and in physical contact with the jacket;
- at least one tube extending alongside and in contact with the metal armor strip along a length of the power cable; and wherein
- each turn of the metal strip extends around the tube and the metal armor strip and is in physical contact with the tube, the metal armor strip and the tubing.

7. An electrical submersible well pump assembly, comprising:
- a pump driven by an electrical motor;
- a string of metal coiled tubing connected to the well pump assembly and adapted to extend to an upper end of a well;
- a power cable installed in the coiled tubing, the power cable comprising:
- three insulated electrical conductors embedded within an elastomeric jacket, the conductors being spaced 120 degrees apart from each other relative to a centerline of the power cable, the jacket having a cylindrical exterior;
- a metal strip having turns wrapped helically around the jacket, the turns of the metal strip having an inner diameter surface in contact with an outer surface of the jacket and an outer diameter surface in contact with an inner surface of the coiled tubing; and wherein
- the turns of the metal strip are radially deformed relative to the centerline of the power cable between the inner diameter surface and the outer diameter surface such that the metal strip exerts a radial inward force from the inner diameter surface against the outer surface of the jacket and an outward radial force from the outer diameter surface against the inner surface of the coiled tubing to cause the power cable to frictionally grip the coiled tubing.

8. The assembly according to claim **7**, wherein:
- when viewed in a transverse cross section the metal strip has a generally S-shaped configuration, defining an outward facing curved valley and an inward facing curved valley, relative to the centerline of the power cable; and
- the inward facing curved valley of each turn of the metal strip overlaps the outward facing curved valley of an adjacent one of the turns.

9. The assembly according to claim **7**, wherein:
- when viewed in a transverse cross section, each of the turns of the metal strip defines an outward facing curved valley and an inward facing curved valley, relative to the centerline of the power cable, the outward facing curved valley joining the inward facing curved valley at a curved transition area, each of the outward facing and inward facing curved valleys having an edge at a margin of the metal strip;
- the edge of the inward facing curved valley being in contact with an outer surface of the outward facing curved valley; and

the edge of the outward facing curved valley being in contact with an inner surface of the inward facing curved valley.

10. The assembly according to claim **7**, wherein the radial deformation of the metal strip is elastic.

11. The assembly according to claim **7**, further comprising three tubes symmetrically spaced and embedded within the jacket alongside the conductors and extending along a length of the power cable.

12. An electrical submersible well pump assembly, comprising:

a pump driven by an electrical motor;

a string of metal coiled tubing connected to the pump assembly and adapted to extend to a wellhead;

a power cable electrically connected to the motor and extending through the coiled tubing for supplying power to the motor, comprising:

three insulated electrical conductors embedded within an elastomeric jacket;

a metal strip having turns wrapped helically around the jacket, overlapping with each other, and the turns of the metal strip having an inner diameter surface in contact with an outer surface of the jacket and an outer diameter surface in contact with an inner surface of the coiled tubing;

the turns of the metal strip having an initial radial thickness, relative to a centerline of the power cable, and measured from the inner diameter surface to the outer diameter surface prior to installation of the power cable in the coiled tubing; and

the turns of the metal strip having a final radial thickness measured from the inner diameter surface to the outer diameter surface after installation of the power cable in the coiled tubing that is less than the initial radial thickness, so as to create a bias force from the inner diameter surface of the turns of the metal strip against the outer surface of the jacket and from the outer diameter surface of the turns of the metal strip against the inner surface of the coiled tubing.

13. The assembly according to claim **12**, wherein the metal strip is elastically deformed against the outer surface of the jacket and against the inner surface of the coiled tubing.

14. The assembly according to claim **12**, wherein:

when viewed in a transverse cross section, each of the turns of the metal strip defines an outward facing curved valley and an inward facing curved valley, relative to the centerline of the power cable, the outward facing curved valley joining the inward facing curved valley at a curved transition area, each of the outward facing and inward facing curved valleys having an edge at a margin of the metal strip;

the edge of the inward facing curved valley being in contact with an outer surface of the outward facing curved valley; and

the edge of the outward facing curved valley being in contact with an inner surface of the inward facing curved valley.

15. The assembly according to claim **12**, wherein a difference between the initial radial thickness and the final radial thickness of the metal strip is in the range from 0.005 to 0.025 inch.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,725,997 B2
APPLICATION NO. : 14/826422
DATED : August 8, 2017
INVENTOR(S) : Tim W. Pinkston and Don C. Cox

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

Column 5, Line 37 “timing” should be --facing--.

Signed and Sealed this
Twenty-first Day of November, 2017

Joseph Matal

Joseph Matal
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office